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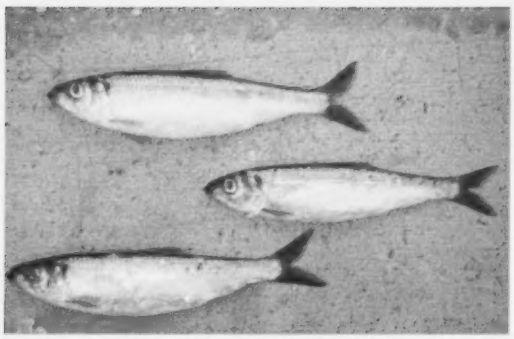
Pacific Region

Canadian Science Advisory Secretariat
Science Advisory Report 2012/062

STOCK ASSESSMENT REPORT ON PACIFIC HERRING IN BRITISH COLUMBIA IN 2012



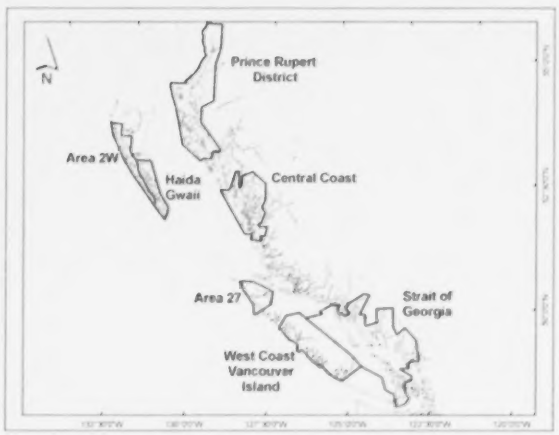


Figure 1. The five major and two minor British Columbia herring stock assessment regions

Context

Pacific herring is a pelagic species inhabiting inshore and offshore waters of the North Pacific. In the eastern Pacific, herring distribution ranges from California to the Beaufort Sea. Herring annually migrate between feeding and spawning areas. Fish mature and recruit to the spawning stock primarily between ages 2 and 5. In British Columbia (BC) herring predominantly recruit at age 3. BC herring stocks are managed based on five major and two minor stock areas. The five major BC herring stocks are Haida Gwaii (Area 2E), Prince Rupert District, Central Coast, Strait of Georgia, and West Coast of Vancouver Island, while the two minor herring stocks are Area 2W and Area 27 (Figure 1). Catch and survey information is collected independently for each of these seven areas and science advice is provided on the same scale.

Fisheries Management Branch annually requests science advice regarding the status of herring stocks in BC and harvest options. Annual stock assessments and forecasts of abundance are carried out using a catch-at-age model. This report summarizes the results of the 2012 annual assessment and provides recommendations on 2012/13 harvest options.

This Science Advisory Report has resulted from a Fisheries and Oceans Canada, Canadian Science Advisory Secretariat Pacific Regional Advisory Meeting. Additional publications from this process will be posted as they become available on the DFO Science Advisory Schedule at http://www.dfo-mpo.gc.ca/csas-sccs/index-eng.htm.

Canada

SUMMARY

- The five major BC herring stocks are Haida Gwaii (Area 2E), Prince Rupert District, Central Coast, Strait of Georgia, and West Coast of Vancouver Island, while the two minor herring stocks are Area 2W and Area 27 (Figure 1).
- The Fishery Management Framework establishes harvest control rules setting the maximum available commercial harvest for each of the major stock areas at 20% of the forecast of mature stock biomass (males and females combined) when the forecast of mature stock biomass is above the commercial fishery threshold or "cutoff", which is 25% of estimated unfished biomass (0.25 B_0). If a forecast exceeds a cutoff, but a 20% harvest rate would result in spawning biomass that is less than the cutoff, the maximum available harvest is determined as the difference between the forecast and cutoff.
- An integrated statistical catch age model (ISCAM) was used to assess the 2012 herring spawning stock biomass, and forecast the 2013 pre-fishery mature stock biomass. The ISCAM model was first reviewed and implemented for the 2011 assessment cycle. Further sensitivity analyses were conducted and reviewed in June of 2012, leading to a recommendation for continued use of the ISCAM model for the 2012 assessment cycle. Additional recommendations include the development of limit and upper stock reference points, compliant with the precautionary approach.
- The following is a summary of the assessment results and advice by management area. All herring biomass results are based solely on output from the 2012 assessment model. Biomass is reported in metric tonnes and all estimates represent median values (and 90% confidence intervals in parentheses) from the joint posterior distribution. B_t denotes estimates of spawning stock biomass.

Haida Gwaii (HG, Area 2E)

- All herring spawning from Cumshewa Inlet in the north to Louscoone Inlet in the south are assumed to be part of the Haida Gwaii stock.
- No commercial herring fishery occurred in this area in 2012 (or 2003-2011).
- The median estimate of the 2012 spawning stock biomass is 17,547 (9,349 – 32,723) tonnes.
- The forecast of mature stock biomass for 2013 is 8,935 (4,843 – 17,225) tonnes (assuming poor recruitment), which is slightly above the fishing threshold of $0.25B_0$ (8,892 tonnes).
- Spawner biomass has remained at a stable but low level over the past 10 years, and there is uncertainty about the cause of current low productivity. Given that there has been limited stock recovery, even in the absence of commercial fisheries, an assessment to determine appropriate rebuilding and harvest strategies is recommended prior to reopening fisheries in this area.

Prince Rupert District (PRD)

- All herring spawning in Statistical Areas 3 to 5 are assumed to belong to the Prince Rupert District stock.
- In 2012, the total roe herring seine fishery validated catch was 466 tonnes and the total roe herring gillnet fishery validated catch was 917 tonnes.
- A commercial spawn-on-kelp fishery occurred in this area in 2012.

- The median estimate of the 2012 post fishery spawning biomass is 26,857 (15,350 – 46,398) tonnes.
- The forecast of mature stock biomass for 2013 is 26,168 (15,477 – 44,636) tonnes (assuming average recruitment), which is above the fishing threshold of $0.25B_0$ (19,107 tonnes).

Central Coast (CC)

- All herring spawning in Kitasu Bay (a portion of Statistical Area 6), in Statistical Area 7, and in part of Statistical Area 8 (Kwakshua Channel and Fitzhugh Sound) are assumed to be part of the Central Coast stock.
- No commercial herring fishery occurred in this area in 2012 (or 2008-2011).
- The median estimate of the 2012 post fishery spawning biomass is 13,747 (7,684 – 23,487) tonnes.
- The forecast of mature stock biomass for 2013 is 10,032 (6,053 – 16,615) tonnes (assuming poor recruitment), which is below the fishing threshold of $0.25B_0$ (14,930 tonnes).
- Spawner biomass has shown a steady decline over the past 13 years, remaining at low levels in the recent 5 years. There is uncertainty regarding the reason for the current low productivity. Given that there has been no evidence of stock recovery in the past 10-years, even in the absence of commercial fisheries, an assessment to determine appropriate rebuilding and harvest strategies is recommended prior to reopening fisheries in this area.

Strait of Georgia (SOG)

- All herring spawning in Statistical Areas 14 to 19, 28 and 29 (excluding Section 293), and part of 13 (Herring Sections 132 and 135, Deepwater Bay area south) are assumed to belong to the Strait of Georgia herring stock.
- In 2012, the total winter seine fishery (food and bait and special use) validated catch was 4,090 tonnes; the total roe herring seine fishery validated catch was 3,170 tonnes and the total roe herring gillnet fishery validated catch was 4,079 tonnes.
- The median estimate of the 2012 post fishery spawning biomass is 97,802 (56,173 – 167,387) tonnes.
- Spawner biomass has fluctuated over the past 10 years.
- The forecast of mature stock biomass for 2013 is 82,952 (47,069 – 142,361) tonnes (average recruitment forecasted based on summer trawl observations), which is above the fishing threshold of $0.25B_0$ (33,318 tonnes).

West Coast Vancouver Island (WCVI)

- All herring spawning in Statistical Areas 23 to 25 are assumed to belong to the west coast of Vancouver Island herring stock.
- No commercial fishery occurred on the west coast of Vancouver Island in 2012 (or 2006-2011).
- The median estimate of the 2012 post fishery spawning biomass is 13,698 (7,490 – 24,095) tonnes.

- The forecast of mature stock biomass for 2013 is 10,989 (6,971 – 17,978) tonnes (poor recruitment forecasted based on summer trawl observations), which is below the fishing threshold of $0.25B_0$ (14,067 tonnes).
- Science voiced concerns over data quality for 2012 (such as missing spawn and low number of biological samples).
- Spawner biomass has remained at relatively low levels and there is uncertainty about the cause of current low productivity. Given that there has been limited stock recovery, even in the absence of commercial fisheries, an assessment to determine appropriate rebuilding and harvest strategies is recommended prior to reopening fisheries in this area.

Area 2W

- All herring spawning in Statistical Area 2W (except Herring Section 006) are assumed to belong to this Haida Gwaii minor stock.
- A commercial spawn-on-kelp fishery occurred in this area in 2012.
- The median estimate of the 2012 post fishery spawning biomass is 5,707 (2,421 – 12,103) tonnes.
- The forecast of mature stock biomass for 2013 is 5,327 (1,923 – 12,630) tonnes (assuming average recruitment).

Area 27

- All herring spawning in Statistical Area 27 are assumed to belong to this West Coast of Vancouver Island minor stock.
- A commercial spawn-on-kelp fishery occurred in this area in 2012.
- The median estimate of the 2012 post fishery spawning biomass is 1,109 (588 – 2,101) tonnes.
- The forecast of mature stock biomass for 2013 is 1,154 (663 – 2,077) tonnes (assuming average recruitment).

INTRODUCTION

Species Biology

Pacific herring is a pelagic species migrating between inshore spawning and offshore feeding areas of the North Pacific. In the eastern Pacific, herring distribution ranges from California to the Beaufort Sea. Herring mature and recruit to the spawning stock predominantly at age 3 within British Columbia but age-at-recruitment tends to increase with latitude within this range.

Stock Structure

For the purposes of evaluation and management, British Columbia herring stocks are defined as five major and two minor stocks (Figure 1). Stock structure is supported both by multi-year tagging and genetic studies (Hourston, 1982, Beacham et al., 2008, Flostrand et al., 2009). The major stocks are: Haida Gwaii (HG, Area 2E and formerly referred to as Queen Charlotte Islands), Prince Rupert District (PRD), Central Coast (CC), Strait of Georgia (SOG) and West Coast of Vancouver Island (WCVI). The two minor herring stocks are Area 2W and Area 27. Smaller scale spatial delineations related to fishing and sampling activities are Statistical Areas (http://www.pac.dfo-mpo.gc.ca/fm-gp/maps-cartes/areas-secteurs/index-eng.htm) and Herring Sections (http://www.pac.dfo-mpo.gc.ca/science/species-especes/pelagic-pelagique/herring-hareng/herspawn/pages/default0-eng.htm).

Ecosystem Considerations

As a forage species, herring play a key role in the marine ecosystem and are a food source for a variety of species (Schweigert et al., 2010). Herring are an important prey species to many piscivores including Pacific salmon (Coho and Chinook), Pacific hake, halibut, arrowtooth flounder, and dogfish. They are also believed to be important in the diet of marine mammal predators such as Steller and California sea lions, harbour and northern fur seals, harbour porpoises, Pacific white-sided dolphins, humpback and grey whales. Over the time series depicted in the Pacific herring assessment (1951-2012), population sizes of seals and sea lions and baleen whales, which forage on herring, have increased (DFO 2003; DFO, 2010; Carretta et al 2011; Crawford & Irvine, 2011).

Research continues to develop a fuller understanding of ecosystem processes and the role that herring play in maintaining ecosystem integrity and function. Little information is available to develop ecosystem-based conservation limits for herring, however, because there is no targeted commercial harvest of immature herring and the current maximum harvest rate of 20% is believed to be conservative, most juveniles and a significant proportion of the adult population should remain available to support ecosystem processes. An ecosystem approach for developing biological limit reference points for BC herring stocks is a priority area of research for DFO.

History of the Fishery

Herring have been harvested for many years to provide a variety of food products. First Nations have traditionally harvested herring and herring spawn for food, social and ceremonial purposes. From the early 1930s to the late 1960s, herring were commercially harvested and processed (reduced) into relatively low-value products such as fishmeal and oil. Figure 2 shows trends depicting total quantities of commercial removals from 1951 to 2012. Commercial catches increased dramatically in the early 1960s, but were unsustainable. By 1965, most of the older fish

had been removed from the spawning population by a combination of overfishing and by a sequence of weak year-classes attributed to unfavourable environmental conditions and a low spawning biomass. As a result, the commercial fishery collapsed and was closed by the federal government in 1967 to rebuild the resource. During the closure from 1967-1971, limited fishing activity occurred at low levels (Hourston, 1980). At this time, there was a growing interest in harvesting roe herring for export to Japan, where herring stocks had become decimated. A small experimental roe harvest began in 1971 and expanded rapidly until 1983, when a fixed harvest rate was introduced to regulate catch. A series of above average year-classes occurred in the early 1970s, rapidly rebuilding stocks and permitting the re-opening of areas for commercial fishing.

Today, the fishery is comprised of: commercial fishing opportunities for food and bait herring, spawn-on-kelp products, and roe herring; a food, social, and ceremonial fishery for First Nations; and recreational opportunities. Table 1 shows combined commercial removals from 2007 to 2012 from roe and food and bait (includes special use) fisheries operating in the five major and two minor BC herring stock assessment areas.

Table 1. Combined commercial removals from roe, and food and bait (includes special use) fisheries operating in the BC herring stock assessment areas (tonnes), 2007-2012. Removals associated with the spawn-on-kelp fishery are not included in totals.

	2007	2008	2009	2010	2011	2012
Haida Gwaii	0	0	0	0	0	0
Prince Rupert District	970	1,662	2,000	1,484	2,147	1,383
Central Coast	398	0	0	0	0	0
Strait of Georgia	9,822	9,934	10,170	8,324	5,128	11,339
West Coast Vancouver Island	0	0	0	0	0	0
Area 2W	0	0	0	0	0	0
Area 27	0	0	0	0	0	0

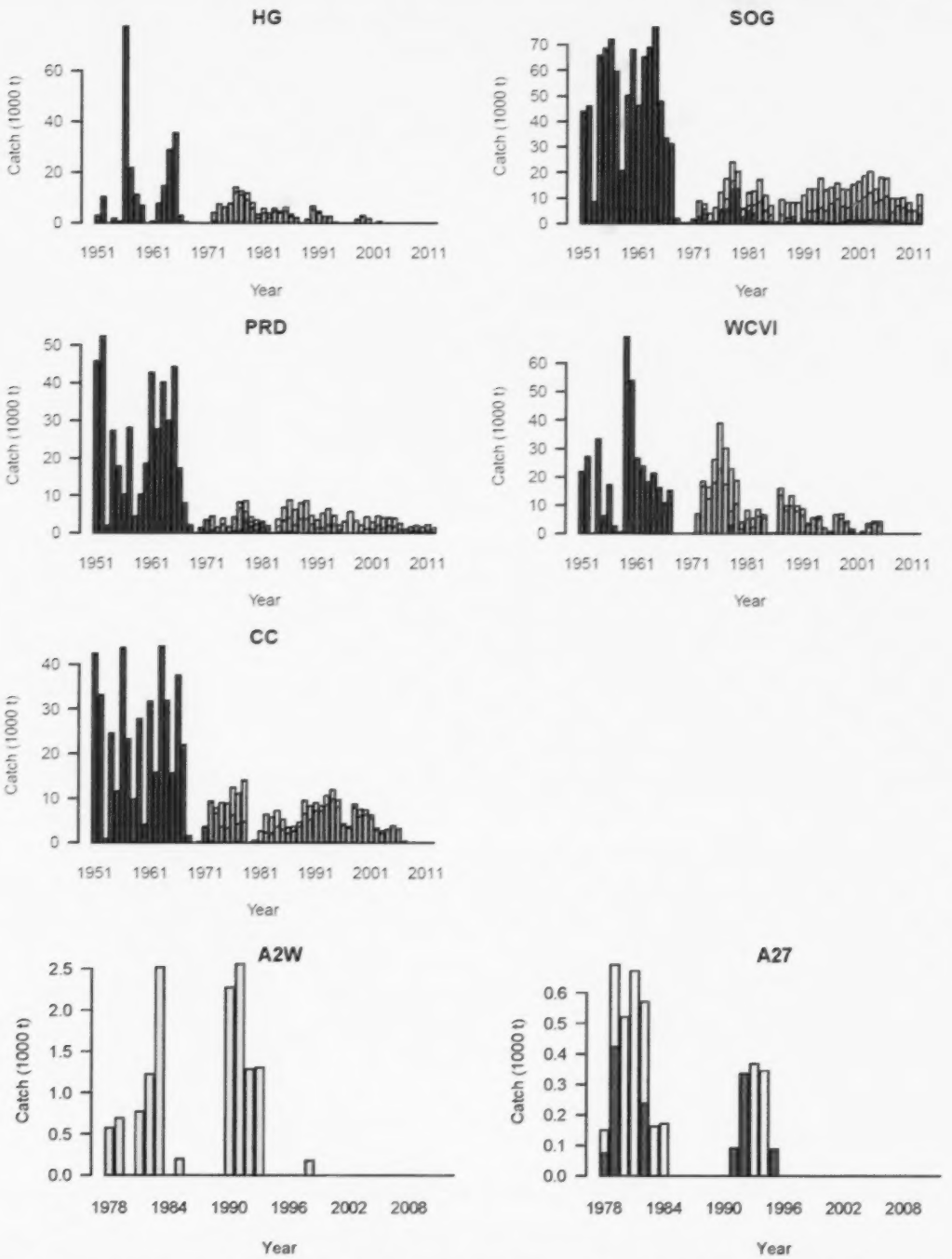


Figure 2. Historical catch of herring in the five major (1951-2012) and two minor (1978-2012) stocks for the winter purse seine fishery (dark bars): seine-roe fishery (grey bars), and gill net fishery (light grey bars). Spawn on kelp fishing not represented. Catch units are in thousands of metric tonnes and scales differ between panels.

Management Framework

The objective of the current herring management framework is to sustainably manage the available biomass in a manner that conserves and protects Pacific herring stocks, their habitat, and ecosystem processes, and provides fishing opportunities for First Nations food, social, ceremonial and commercial purposes, and commercial, and recreational harvesters. The present-day fishery is managed using a management framework developed based on previously reviewed and endorsed science advice that incorporates a fixed harvest rate policy and a formal harvest control rule or commercial fishery threshold, also referred to as the "cutoff."

Maximum available commercial harvest for each of the major stock areas has been 20% of the forecast of mature stock biomass (males and females combined) when the forecast of mature stock biomass is above the commercial fishery threshold or "cutoff." If a forecast exceeds a cutoff but a 20% harvest rate would result in spawning biomass that is less than the cutoff, the maximum available harvest is determined as the difference between the forecast and cutoff. The cutoff for each major area is established as 25% of the estimate of unfished mature stock biomass (B_0). Past research indicates the threshold of $0.25B_0$ maintains the reproductive capacity of the stock (Haist, Fournier, and Schweigert 1993). Fixed estimates of $0.25B_0$ calculated from 1996 estimates of B_0 were applied as the "cutoff" from 1996-2010. In 2011, estimates of B_0 were updated using the stock assessment model, and revised estimates are again presented for 2012.

Maximum available commercial harvest for the minor herring stocks (Area 2W and Area 27) has been calculated by applying a precautionary 10% harvest rate to the forecast of mature stock biomass. Commercial fishery thresholds are not established for minor stock areas and recruitment is assumed to be average.

Rationale for Assessment

Advice was requested by Fisheries Management on the current status of the five major and two minor herring stocks and forecasts of pre-fishery biomass for 2013 by stock area for application of the BC herring management framework.

ASSESSMENT

Methodology and Sources of Information

Data collected for use in the assessment of herring stocks are: spawn survey data, commercial catch landings, and age composition data taken from biological samples of the commercial fishery, test fishery and research catches. Herring stock assessment uses information from biological samples for determining the population age composition and average weight-at-age, historical catch, and an assessment of the distribution and intensity of egg deposition in each stock assessment area.

The annual herring stock assessment produces estimates of current abundance, spawning biomass and recruitment, unfished biomass, as well as forecasts of mature stock biomass (pre-fishery) for the upcoming year. A new integrated statistical catch age model (ISCAM) was developed and endorsed for use in determining stock status and provision of harvest advice for the 2011/2012 fishing season. An additional methodological review was conducted in June 2012, to better understand structural assumptions, parameter interactions and their influence on management parameters (B_t, B_0). Modeling changes implemented in 2011 affected the scaling of the biomass estimates in the time series and associated unfished biomass reference point estimates; however, time series trends remain consistent with previous model results.

Stock Trends and Status

Time-series estimates of spawning stock biomass are presented in Figure 3. Table 2 presents estimates of the 2012 spawning biomass, estimates of unfished spawning biomass, and depletion ratios for the major and minor stock areas (where available). Depletion is defined as the ratio of a given year's estimated spawning biomass to an estimate of the average unfished spawning biomass (B_t/B_0). For comparisons, Table 3 presents estimates of spawning stock biomass for 2007-2011. Figure 4 shows trends of the numbers of age-3 recruits and demarcates boundaries for poor, average and good category ranges. Percentages of age-3 recruits described below are based on numbers of fish.

Haida Gwaii (QCI 2E)

Spawning biomass has remained at a low and stable level over the past 10 years, similar to levels in the late 1960s, with a slight increase in the last 2 years. Current stock biomass is estimated to be depleted to 49% of the average unfished biomass level. Median spawning biomass is estimated at 17,547 (9,349 – 32,723) tonnes in 2012. Recruitment of age-3 fish in 2012 was average, comprising 17% of returns.

Prince Rupert District

Spawning biomass has remained at an intermediate and stable level over the past decade with median spawning biomass estimated at 26,857 (15,350 – 46,398) tonnes in 2012. Current stock biomass is estimated to be depleted to 35% of the average unfished biomass level. Recruitment of age-3 fish in 2012 was poor, comprising 13% of returns.

Central Coast

Spawning biomass has declined over the past 13 years, and in the recent 5 years spawning biomass is similar to historical low levels in the late 1960s. Current stock biomass is estimated to be depleted to 23% of the average unfished biomass level. Spawning biomass for the stock is estimated at 13,747 (7,684 – 23,487) tonnes in 2012. Recruitment of age-3 fish in 2012 was poor, comprising 21% of returns.

Strait of Georgia

Spawning biomass has fluctuated over the past 10 years, with spawning biomass for the stock estimated at 97,802 (56,173 – 167,387) tonnes in 2012. Current stock biomass is estimated to be depleted to 73% of the average unfished biomass level. Age-3 recruitment during the past decade has been average or good in all years, except for poor recruitment in 2008 and 2010. Several of the largest recruitment levels observed since 1951 occurred in the past 15 years. Recruitment of age-3 fish in 2012 was good, comprising 39% of returns.

West coast Vancouver Island

Estimates of spawning biomass in 2007-2012 are among the lowest levels observed in the 62-year time series of data for this stock. Current stock biomass is estimated to be depleted to 24% of the average unfished biomass level. Spawning biomass for the stock is estimated at 13,698 (7,490 – 24,095) tonnes in 2012. Since 2004, age-3 recruitment has been relatively poor. Recruitment of age-3 fish in 2012 was poor, comprising 28% of returns. There has been little evidence of stock recovery in this area.

Area 2W

Spawning biomass for the stock shows a gradual increase over the recent 5 years with 2012 spawning biomass estimated at 5,707 (2,421 – 12,103) tonnes. Recruitment of age-3 fish in 2012 comprised 12% of returns.

Area 27

Stock abundance has remained at stable but low level over the past 10 years, with median spawning biomass estimated at 1,109 (588 – 2,101) tonnes. Recruitment of age-3 fish in 2012 comprised 9% of returns.

Table 2. Median (and 90% confidence interval) estimates of the 2012 herring spawning biomass (B_{2012}), unfished biomass (B_0), and depletion ratios (B_{2012}/B_0) for the major and minor herring stock areas (where available). All values in tonnes.

	B_{2012}			B_0			B_{2012}/B_0
Stock	**Median**	**5.0%**	**95.0%**	**Median**	**5.0%**	**95.0%**	**Median**
HG	17,547	9,349	32,723	35,567	26,973	49,417	0.49
PRD	26,857	15,350	46,398	76,427	55,011	127,887	0.35
CC	13,747	7,684	23,487	59,719	48,266	77,407	0.23
SOG	97,802	56,173	167,387	133,272	10,880	169,980	0.73
WCVI	13,698	7,490	24,095	56,268	45,469	70,232	0.24
Area 2W	5,707	2,421	12,103	-	-	-	-
Area 27	1,109	588	2,101	-	-	-	-

Table 3. Median estimates of herring spawning biomass for BC herring stock assessment areas (tonnes), 2007-2012. All estimates based on 2012 input data and model formulation.

Stock	2007	2008	2009	2010	2011	2012
HG	10,690	9,839	12,243	11,365	12,439	17,547
PRD	18,668	18,778	19,355	22,078	26,020	26,857
CC	12,776	11,842	15,502	14,311	14,857	13,747
SOG	108,007	70,540	73,179	60,223	91,719	97,802
WCVI	7,766	7,024	7,982	8,906	12,004	13,698
Area 2W	1,920	2,335	3,806	4,757	5,395	5,707
Area 27	1,721	1,505	1,685	1,472	1,337	1,109

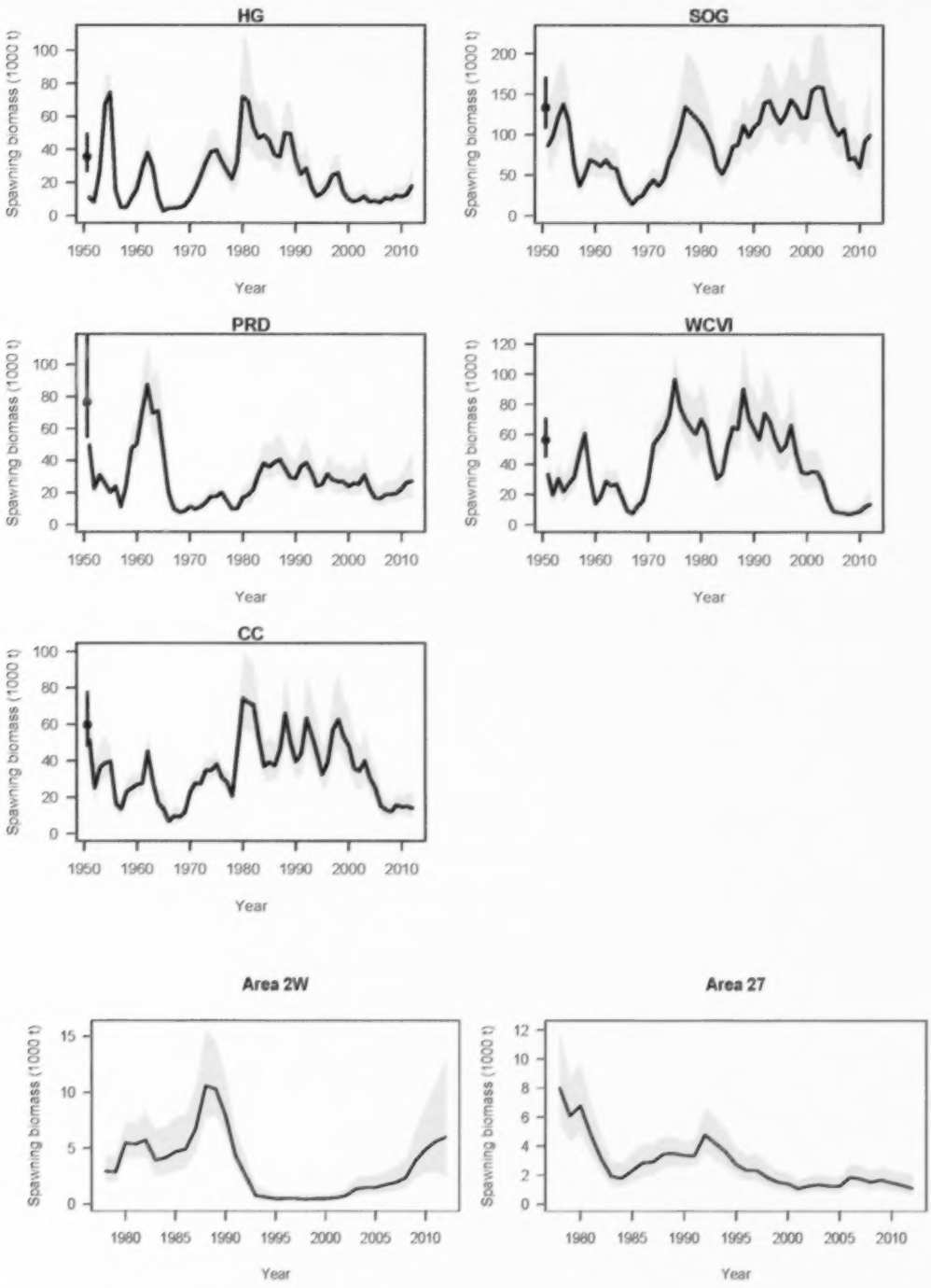


Figure 3. Median posterior density estimates of spawning stock biomass (B_t) for the five major and two minor stock areas. The shaded envelope represents 90% of the distribution in estimates of B_t. Dark circle and extending vertical lines (at year 1950) represent the median estimates of unfished biomass (B_0) and their distribution, for the major stocks only. Biomass is in thousands of metric tonnes and scales differ between panels.

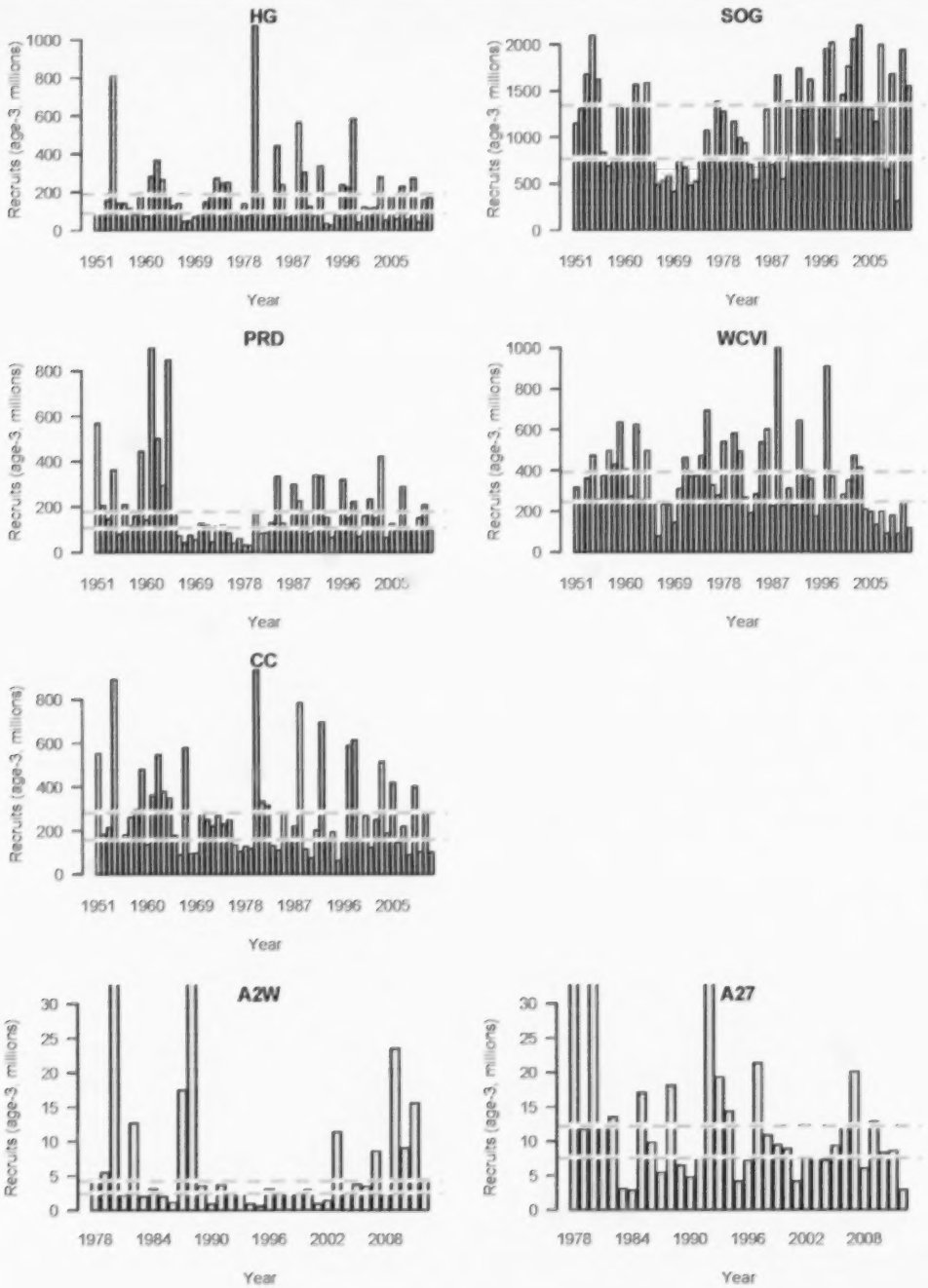


Figure 4. Estimated numbers of age-3 recruits presented for each of the five major (1951-2012) and two minor (1978-2012) stock areas. Lower horizontal dashed line represents lower 33rd percentile of recruits; upper horizontal dashed line represents upper 67th percentile of recruits. Dashed lines demark recruitment categories of poor, average and good. Note: scales differ between panels.

Biomass Forecasts for 2013

Forecasts of mature stock biomass are made by adding estimates of surviving repeat spawners (age 4 and older) to estimates of age-3 recruits. Recruitment of age-3 fish is estimated as the number of age-3 fish recruited to the stock at the end of each year prior to the fishery. Recruitment is categorized as poor, average or good, and model estimates of recruitment are calculated as the medians of the lower 33%, middle 33% and upper 33% of the number of age-3 fish over the entire time series.

Recruitment is determined for the Strait of Georgia and west coast of Vancouver Island stocks based on independent estimates from a summer trawl survey (Tanasichuk, 2000, 2002). Forecasts of age-3 recruits for the two minor herring stocks (Area 2W and Area 27) are determined by assuming "average" recruitment. Forecasts of age-3 recruits for the other three major areas are determined using recruitment forecast rules, which were developed in 2004 (DFO. 2004).

Table 4 provides forecasts of pre-fishery mature stock biomass for each major and minor area under varying recruitment scenarios. When recruitment-forecasting rules are applied, 2013 recruitment is assumed to be "poor" for Haida Gwaii and Central Coast, and "average" for Prince Rupert District and the two minor stock areas (Area 2W and Area 27). Based on analysis of offshore trawl survey data, recruitment is estimated to be "poor" for the West Coast of Vancouver Island stock and "average" for the Strait of Georgia.

Table 4. Median (and 90% confidence interval) biomass estimates (in tonnes) of age 4 and older repeat spawners (4+) and forecasts of pre-fishery mature stock biomass for 2013. Underlined values indicate assigned recruitment forecasts.

	4+Biomass			Forecast Biomass (tonnes) by Recruitment Option			Cutoff $0.25B_0$	Potential[1] Commercial Harvest
Stock	**Median**	**5.0%**	**95.0%**	**Poor**	**Average**	**Good**	**Median**	**(tonnes)**
HG	6,971	3,156	14,745	**8,935**	11,477	18,384	8,892	43
PRD	20,129	10,362	37,223	23,081	**26,168**	35,282	19,107	5,234
CC	6,827	3,460	12,637	**10,032**	12,965	20,782	14,930	0
SOG	49,432	23,419	97,500	67,982	**82,952**	104,488	33,318	16,590
WCVI	5,967	2,942	11,787	**10,989**	15,280	22,457	14,067	0
Area 2W	5,074	1,745	12,272	5,183	**5,327**	6,110	-	533
Area 27	744	348	1,537	943	**1,154**	1,753	-	115

[1]*Potential harvest is based on previously approved harvest control rules that apply a stock-specific commercial fishery cutoff and a harvest rate of 20% for major stock assessment areas and 10% harvest rate for minor stock assessment areas. In cases where the forecast is greater than the cutoff but a 20% harvest rate would reduce the spawning biomass to below the cutoff, the maximum harvest yield is equal to the difference between the forecasted and cutoff amounts (DFO 2011 IFMP). Confidence intervals for forecasts are provided in Summary section (pages 2-4).*

Sources of Uncertainty

Recruitment and natural mortality are considered to be the most important processes determining the productivity of British Columbia herring populations. Various studies have suggested that herring recruitment is determined by variations in the size of the parent stock, and environmental conditions during the first year of life. Research has shown that both recruitment and adult survival tend to be below average in warm years, particularly when migratory herring-predators (like Pacific hake and

mackerel) are abundant off the west coast of Vancouver Island (Ware 1991). The west coast of Vancouver Island herring stock shows an inverse relationship between sea-surface temperature (SST) and herring production. Research is on-going and includes: monitoring of juvenile herring stocks in the SOG and monitoring of zooplankton abundance for the WCVI.

Given the significance of recruitment to herring stock productivity, an evaluation of current recruitment forecasting methods and comparisons with other sources of data (e.g., Strait of Georgia and Central Coast juvenile herring inshore purse seine surveys) and modeling approaches warrants further research.

Uncertainties in the modeling of key parameters (such as gear selectivity, the conversion factor between spawn index and spawner biomass, "q", and the estimation of natural and fishing mortality) have a significant influence on model reconstructions of stock abundance, which are used to provide management advice. Interactions amongst key parameters within the new model structure were thoroughly investigated, however further work is needed to understand the policy implications of the structural changes to the model and any impacts on the performance of the existing harvest control rule. This includes investigation of the use of revised (annually updated) estimates of unfished biomass, used to calculated $0.25B_0$, as opposed to use of a fixed cutoff as was implemented from 1996-2010.

For areas where spawn-on-kelp fisheries occur, considerable uncertainty exists around the true levels of herring use and fishing mortality. The current assessment framework does not account for herring use, mortality, or egg removals, however it is recognized that work is required to quantify these variables in future assessments.

Authors identified a number of uncertainties related to data quality and the implications for increased uncertainty in science advice. For example, it was noted that in 2012 there was a reduction in the number of biological samples collected and weather-days hindered the ability to survey all spawning events in some areas.

CONCLUSIONS AND ADVICE

The Pacific herring stock assessment model was reviewed in 2011 and used to provide stock assessment advice for the 2011/12 fishing season. Further sensitivity analyses were conducted and reviewed in June of 2012, leading to a recommendation for continued use of the ISCAM model for the 2012 assessment cycle providing current estimates of spawning biomass and forecasts for 2013. The spawning stock biomass estimates for 2012 and revised estimates of B_0 are provided in Table 2. Biomass forecasts for 2013 along with revised estimates of $0.25B_0$ (value of fishery "cutoffs" under current harvest control rules), and corresponding harvest control rule yield options are provided in Table 4.

Haida Gwaii, Central Coast and west coast of Vancouver Island stocks all remain near historical low levels of stock biomass. There has been little evidence of stock recovery in these areas, even with an absence of commercial fishing in recent years. The causes of the recent trends in low productivity in these areas are unknown, and more work is required to evaluate ecosystem and environmental drivers. Therefore, it is recommended that biologically based, limit reference points be developed to inform management and rebuilding strategies.

Research and assessment priorities that were identified during this assessment include the development of reference points, consistent with the current DFO Policy on the Application of the Precautionary Approach (PA) for all stocks, an evaluation of the current management framework against the PA, an evaluation into methods for forecasting recruitment, and an investigation into causes of recent trends in low productivity in Haida Gwaii, Central Coast and west coast Vancouver Island stocks.

Under the assumption of "Poor" age-3 recruitment for the Central Coast and west coast of Vancouver Island stocks, the forecast of the 2013 mature stock biomass for these areas is below the respective estimates of 0.25 B_0.

Under the assumption of "Poor" age-3 recruitment for the Haida Gwaii stock, the forecast of the 2013 mature stock biomass is 8,935 tonnes, which is 43 tonnes greater than the estimate of $0.25B_0$ (8,892)

Under the assumption of "Average" recruitment for the Prince Rupert District, the forecast of the 2013 mature stock biomass is 26,168 tonnes, which is greater than the estimate of $0.25B_0$ (19,107).

The Strait of Georgia stock spawning biomass has increased since the recent relative low in 2009, due to strong 2006 and 2008 year-classes. Under the assumption of "Average" age-3 recruitment for the Strait of Georgia, the forecast of the 2013 mature biomass is 82,952 tonnes, which is greater than the estimate of $0.25B_0$ (33,318 tonnes).

Assessment of the Area 2W stock indicates that abundance has gradually increased over the recent 5-years with 2012 spawning biomass estimated at 5,707 tonnes. Under the assumption of "Average" age-3 recruitment for the Area 2W stock, the forecast of the 2013 mature stock biomass is 5,327 tonnes.

Assessment of the Area 27 stock indicates that abundance has shown some gradual declines in the past five years, with a 2012 spawning biomass estimate of 1,109 tonnes. Under the assumption of "Average" age-3 recruitment for the Area 27 stock, the forecast of the 2013 mature stock biomass is 1,154 tonnes.

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